(54) Title: LIQUID CRYSTAL DEVICE

(57) Abstract

A liquid crystal device comprises a layer of nematic or long pitch cholesteric liquid crystal material contained between two cell walls. One wall (A) carries a surface treatment giving a first azimuthal alignment direction with or without a surface pretilt to liquid crystal molecules. The other wall (B) carries a surface treatment (17) capable of separately providing both a preferred, substantially homeotropic alignment of the adjacent liquid crystal, and a defined azimuthal second alignment direction to the adjacent liquid crystal dependent upon liquid crystal molecular arrangement. The first and second alignment directions are approximately orthogonal. The device is formed into an array of separately addressable pixels, e.g. an x, y matrix array. Each pixel may be addressed via an active matrix e.g. thin film transistors, or in an rms. multiplex manner via row and column electrodes. Polarisers may be arranged on either side of the cell walls with their polarisation axes parallel or perpendicular to the two azimuthal directions. Alternatively an amount of dichroic dye may be incorporated in the liquid crystal material, and the device operated with one or two polarisers. The device operates between two different voltage levels, one level providing a non twisted liquid crystal molecular arrangement, the other and higher voltage providing a twisted molecular arrangement. The two polarisers, or dye plus polarisers, distinguishes between the two molecular arrangements in a manner similar to that of prior art twisted nematic devices.

LIQUID CRYSTAL DEVICE

This invention relates to the alignment and switching of nematic liquid crystal devices.

Liquid crystal devices typically comprise of a thin layer of a liquid crystal material contained between cell walls. Optically transparent electrode structures on the walls allow an electric field to be applied across the layer causing a re-ordering of the liquid crystal molecules.

There are three known types of liquid crystal material nematic, cholesteric and smectic each having different molecular ordering. The present invention concerns devices using nematic materials.

In order to provide displays with a large number of addressable elements it is common to make the electrodes as a series of row electrodes on one wall and a series of column electrodes on the other cell wall. These form e.g. an x,y matrix of addressable elements or pixels and for twisted nematic types of device are commonly addressed using rms. addressing methods.

Twisted nematic and phase change devices are switched to an ON state by application of a suitable voltage and allowed to switch to an OFF state when the applied voltage falls below a lower voltage level, i.e. these devices are monostable. For a twisted nematic type of device (90° or 270° twist as in US 4,596,446) the number of elements that can be rms. addressed is limited by the steepness of a device transmission verses voltage curve (as described by Alt and Pleschko in IEEE Trans ED vol ED 21, (1974) P.146 - 155).

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One way of improving the number of pixels is to incorporate thin film transistors adjacent to each pixel; such displays are termed active switching element and include switching elements such active matrix displays.

5   An advantage of nematic types of devices is the relatively low voltage requirements. They are also mechanically stable and have a wide temperature operating range. This allows construction of small and portable battery powered displays.

The main disadvantages of the above devices are as follows. The 90° twisted
10   nematic has a poor viewing characteristic which leads to loss of contrast when the device is viewed at high incident angles in certain azimuthal directions. Furthermore greyscale inversion occurs in these orientations. The low steepness of the 90° twisted nematic can be improved by increasing the twist angle to 180° - 270°. However this generally leads to no improvement in viewing characteristic. Both types of device also
15   suffer from the fact that the large difference in the nematic tilt between the on and off states leads to a change in pixel capacitance which can cause crosstalk problems with other pixels.

According to this invention the above disadvantages are overcome using a surface
20   treatment on one cell wall which treatment consists of an azimuthal alignment direction in a material or coated material which ordinarily induces a homeotropic orientation of the nematic director together with an alignment treatment on the other cell wall giving homogeneous alignment; the liquid crystal material has a negative dielectric anisotropy. This device may be called a VCT (voltage controlled twist
25   device) configuration. It allows a steep optical response to be obtained with a greatly improved viewing characteristic. Furthermore only a small change in pixel capacitance occurs when the pixel is switched which leads to improved active matrix addressing and also less crosstalk in rms. addressing.

According to this invention a liquid crystal device comprises;

a nematic or chiral nematic liquid crystal of negative dielectric anisotropy;

5   two containing walls, spaced apart and each so treated as to align the liquid crystal adjacent to them and carrying electrodes or other means to impose a field on the liquid crystal layer;

means for distinguishing between two different optical states;

10

CHARACTERISED BY:

an aligning surface treatment at one cell wall providing a substantially planar or tilted alignment of the liquid crystal with a defined azimuthal first alignment direction;

15

an aligning surface treatment on the second cell wall capable of separately providing both a preferred, substantially homeotropic alignment of the adjacent liquid crystal, and a defined azimuthal second alignment direction to the adjacent liquid crystal dependant upon liquid crystal molecular arrangement;

20

the first and second azimuthal alignment directions being at a non zero angle to one another.;

the arrangement being such that the liquid crystal material may adopt a twisted and a

25   substantially non twisted molecular arrangement dependant upon applied electric fields.

The first and second azimuthal alignment directions may be substantially perpendicular or within 10° of perpendicular. The polarisers optical axis may be orthogonal, or within about 10° of being orthogonal. Additionally, the two polarisers may be rotated relative to the cell to obtain maximum contrast between the two states

5   of the device.

The alignment at said second cell wall may comprise an alignment treatment ordinarily providing homeotropic alignment, in conjunction with a relief grating structure. The grating may be symmetric or asymmetric in profile, the groove depth

10   and or pitch may be constant or may vary between pixels or within one pixel. Furthermore the grating groove direction may be constant or may vary between pixels or within one pixel. The grating surface may contain more than one modulation.

15   The alignment at said second cell wall may comprise an alignment treatment ordinarily providing homeotropic alignment, in conjunction with a rubbed polymer, or in conjunction with an evaporated inorganic layer such as MgF_2.

The defined azimuthal alignment direction at said second cell wall may be provided

20   by an anisotropic photoactive polymer layer.

The grating may be a profiled layer of a photopolymer formed by a photolithographic process e.g. M C Hutley, Diffraction Gratings (Academic Press, London 1982) p 95-125; and F Horn, Physics World, 33 (March 1993). Alternatively, the bigrating may

25   be formed by embossing; M T Gale, J Kane and K Knop, J App. Photo Eng, 4, 2, 41 (1978), or ruling; E G Loewen and R S Wiley, Proc SPIE, 88 (1987), or by transfer from a carrier layer.

The planar surface may be a grating or a rubbed polymer or an anisotropically photopolymerised photopolymer or any other treatment which induces a substantially parallel (or a surface pretilt of typically 2 to 15°) orientation of the nematic director

5 with respect to the surface with a preferred azimuthal direction.

The alignment on one or both walls may be formed by the technique of oblique evaporation of e.g. MgF_2 etc.

10 The electrodes may be formed as a series of row and column electrodes arranged as an x,y matrix of rms. addressable elements or display pixels at electrode intersections. Typically the electrodes are 200μm wide spaced 20μm apart. The electrodes may be addressed by row and column driver circuits.

15 Alternatively, the electrodes may be arranged in other display formats e.g. r-θ matrix or 7 or 8 bar displays.

The cell walls may be substantially rigid plates of glass. Alternatively, one or both walls may be of a flexible material, e.g. a plastics material such as POLYOLEFIN,

20 PET.

The pixels may be addressed by an array of active switching elements, e.g. active matrix elements such as thin film transistors (TFT). In this case the TFT are formed on the surface of one cell wall and switched by e.g. x, y electrodes on the same cell

25 wall; the second cell wall has formed thereon a single sheet or common plate electrode. One of these x,y electrodes is shaped into a pixel shape.

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The means for distinguishing between two different optical states may be polarisers. Alternatively the means may be a small amount, e.g 1 to 5% of a dichroic dye

5   included in the liquid crystal material together with one or two polarisers. Typical dyes are 2-4% of D102 (Merck), and about 4% of D6 (Merck).

Small amounts of a chiral dopant or cholesteric liquid crystal material, eg about 3% of C15 (Merck), may be added to the nematic liquid crystal material to impart a

10   preferred twist direction.

The principle of operation is as follows. When a field is applied to the cell, the negative nematic material is forced to reduce its tilt angle until virtually the entire cell thickness is in a planar low tilt state with no twist. When the field is further increased,

15   the planar configuration is forced closer to the homeotropic surface until the liquid crystal begins to interact with the alignment direction that is contained within the homeotropic surface. If this alignment direction is non parallel to the alignment direction of the opposite planar surface then this interaction will lead to twist. With suitable arrangements of polarisers, this twisting is accompanied by a change in

20   optical transmission and hence the device acts as an optical switch.

The planar non twisted (off) state will appear dark if crossed polarisers are oriented parallel and perpendicular to the planar alignment direction. Furthermore this state appears dark when viewed from any direction. The twisted (on) state will appear

25   bright. Therefore this display mode will possess a high contrast regardless of viewing direction. Also the 'off' to 'on' switching event occurs with minimal change in liquid crystal tilt angle therefore the capacitance does not undergo a large change.

The invention will now be described, by way of example only with reference to the accompanying drawings of which;

Figure 1 is a plan view of a matrix multiplexed addressed liquid crystal display;

Figure 2 is the cross section of the display of figure 1;

Figure 3 shows a schematic view of one cell wall carrying a matrix of thin film transistors, and two sets orthogonal addressing electrodes, with pixels formed by pixel electrodes;

Figure 4 is a schematic view of the second wall with a sheet electrode, for use with the cell wall of Figure 3.

Figure 5 shows the principle of the device operation;

Figure 6 shows the transmission (solid line) and capacitance (dotted line) as a function of voltage for the device cell;

Figure 7 shows the transmission of the device as a function of voltage for several different grating groove depths.

Figure 8 shows the contrast ratio as a function of viewing orientation for a cell with deep grating grooves.

Figure 9 shows the contrast ratio as a function of viewing orientation for a cell with deep grating grooves.

Figure 10 shows the switching times as a function of liquid crystal material layer thickness.

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The display in figures 1, 2 comprises a liquid crystal cell 1 formed by a layer 2 of nematic or long pitch (e.g. pitch greater than about four time layer thickness) cholesteric liquid crystal material contained between glass walls 3, 4. A spacer ring 5 maintains the walls typically 1-6µm apart. Additionally numerous beads of the same

5   dimensions may be dispersed within the liquid crystal to maintain an accurate wall spacing. Strip like row electrodes 6 e.g. of SnO_2 or ITO are formed on one wall 3 and similar column electrodes 7 are formed on the other wall 4. With m-row and n-column electrodes this forms an m×n matrix of addressable elements or pixels. Each pixel is formed by the intersection of a row and column electrode.

10

A row driver 8 supplies voltage to each row electrode 6. Similarly a column driver 9 supplies voltages to each column electrode 7. Control of applied voltages is from a control logic 10 which receives power from a voltage source 11 and timing from a clock 12.

15

Either side of the cell 1 are polarisers 13, 13' arranged with their polarisation axis P substantially crossed with respect to one another and substantially parallel to the alignment directions R, if any, on the adjacent wall 3, 4 as described later. Additionally a compensation layer of e.g. stretched polymer may be added adjacent

20   to the liquid crystal layer.

A partly reflecting mirror 16 may be arranged behind the cell 1 together with a light source 15. These allow the display to be seen in reflection and lit from behind in dull ambient lighting. For a transmission device, the mirror may be omitted.

25

Prior to assembly, one of the cell walls e.g. wall 3, is provide with a grating structure 17 to give both an alignment direction and a homeotropic orientation. The other cell wall 4 is surface treated to give a planar surface with a preferred alignment direction.

30   Finally the cell is filled with a nematic material which may be e.g. EN38 (Chisso) or ZLI-4788 (Merck).

Figures 3, 4 show an active matrix type of display in which one cell wall 20 carries an array of thin film transistors 21 each connected to one of a souce line (row) electrode 22 and a gate line (column) 23 electrode; each gate line has an extension 24 which extends over to form a part of each TFT 21. Associated with each TFT is a pixel
5 electrode 25. Small electrical insulators 26 at each junction of source and gate electrodes provide isolation between source and gate electrodes. The application of a voltage along a gate electrode connects each pixel electrode 25 to its associated source electrode thereby charging the material under the pixel electrode. The second cell wall 27 carries a sheet like common electrode 28 which connects to earth
10 potential. The row and column drivers 8, 9 of Figure 1 connect to the source and gate electrodes of Figure 3.

The device is caused to display information by switching selected pixels to an ON state on a background of OFF pixels (or visa versa). A pixel is switched to ON by
15 switching a selected pixel TFT to a conducting condition. This causes a voltage to appear on the associated pixel electrode 25 which remains until the voltage is discharged by switching the TFT to ON whilst connecting the source electrode 22 to earth potential. When in the ON state the liquid crystal material, pixel electrode 25 and common electrode 28 form a capacitor which holds its charge until discharge to
20 earth; hence a need for a liquid crystal material having a reasonably constant capacitance in its switched and unswitched states.

Example 1:

The grating on wall 3 was fabricated into Shipley 1805 photoresist by contact
photolithography using a chrome on glass mask with a pitch of 1μm (0.5μm lines,
5   0.5μm gaps). Adjustment of the exposure time allowed different groove depths to be
obtained. In this case a mercury lamp source was used with an intensity of
$0.5mW/cm^2$. Development was carried out in Shipley MF319 for 10 seconds followed
by a water rinse. Finally the grating was exposed to deep UV and baked at 160°C to
ensure insolubility in the liquid crystal. Prior to cell construction, the grating surface
10   was treated with a lecithin solution in order to induce a homeotropic surface.

The alignment on wall 4 consisted of a rubbed layer of PI32 (Ciba Geigy) or a
polyimide. This rubbing gives both an alignment direction and a surface pretilt, e.g. of
2 to 10°.
15
The principle of operation is now described with reference to Figure 5.

The top surface (A) (wall 4) can be any treatment which induces a pretilted planar
alignment (in the x direction) while the lower surface (B) (wall 3) is a grating surface
20   coated with a surfactant to induce a homeotropic orientation. The grating grooves
point in the y direction. At voltage V=0, a hybrid director profile exists as shown in
Figure 3a. When the voltage is raised to V_1, the tilt of the nematic (with $\Delta\epsilon < 0$)
lowers throughout the thickness of the cell except close to the grating surface where
it remains high due to the homeotropic treatment Figure 3b. At a higher voltage (V_2),
25   the nematic very close to (or even within) the grating grooves is driven into a planar
orientation Figure 3c. Once this occurs, the director near the surface will encounter
the azimuthal anchoring force of the grating 17 and will twist around to follow the
groove direction (y axis). Thus a twisted structure is formed.

The two states are made optically distinct by placing the cell between crossed polarisers (Figures 1,2) with their transmission axes along the x and y directions. In this case, the configurations at V=0 and V_1 will appear black while at V_2 a light state is observed.

5

As with conventional TN structures, the maximum transmission is obtained when N is an integer where:

$$N = \sqrt{\left(\Delta nd / \lambda\right)^2 + 0.25}$$

10

where Δn is the nematic birefringence, d is the cell gap and λ is the operating wavelength. Similarly a normally black mode can be obtained by using parallel polarisers along either the x or y direction.

15   The optical contrast is obtained using voltages between V_1 and V_2. In this range the nematic director is substantially planar and so the black and white states as well as intermediate grey levels are obtained with improved and symmetric viewing angle characteristics. Variation of the grating groove depth influences the voltage at which the transition to a twisted state occurs. A higher transition voltage is preferred to

20   ensure a fully planar structure. Several experiments have been carried out as described below.

One cell was made using a grating surface which was formed from a 100 seconds exposure. This 10μm thick cell was filled with EN38 (Chisso) and optical observation

25   confirmed that the zero volts state was splayed as in Figure 5. Eye response transmission was then measured with the cell between crossed polarisers and capacitance data was also taken.

Figure 6 (solid line) shows that the transmission at V=0 is low.   At about 4V it begins to rise which corresponds to the transition between the $V=V_1$ and $V=V_2$ configurations in Figure 5. Furthermore the results clearly show that the capacitance (broken line) has almost fully saturated before the transmission begins to rise. Hence

5   it can be concluded that the majority of the cell thickness is planar before the twist deformation occurs. Thus the greyscale in the VCT is mainly due to a voltage controlled twist and so a good viewing characteristic will be obtained. The data also shows that optical switching can occur with only small changes in capacitance.

10   In the next experiment several cells were fabricated using gratings formed with different exposure time to test the effect of groove depth on the switching response. The cells had a gap of 5μm and were filled with EN38. Figure 7 shows the optical transmission of these cells as a function of voltage. The quoted groove depths were measured using tapping mode AFM (atomic force microscopy). The curves clearly

15   show that the optical threshold is very sensitive to the grating groove depth with deeper grooves (longer exposures) leading to a threshold at a lower voltage. In all cases, high contrast switching is obtained (>200:1). The curves with lower voltage thresholds also show optical responses which are steeper than typical 90° TN devices.

20

Operation of the device can be considered as follows.   The change in twist threshold voltage cannot be attributed to the extent to which the grating grooves extend into the cell as the groove depth in the above samples has only been varied between 0.085μm and 0.54μm, both of which are small compared to the cell gap (5μm).

25   Instead, we need to consider the size and extent of the distortion of the nematic above the grating surface.

The grating surface imposes an azimuthal anchoring energy ($W\phi$) which forces the nematic director to lie parallel to the grating grooves which is given by (D. W. Berreman, Mol.Cryst. Liq. Cryst. V. 23, P.215 (1973));

5

$$W_\phi \propto \frac{a^2}{L^3}$$

where a is the groove depth and L is the grating pitch. $W\phi$ is the total energy per unit area integrated in the z direction to infinity. The decay length in the z direction will be proportional to the grating pitch and almost independent of the grating groove depth.

10   Therefore separate adjustment of a and L allow independent adjustment of the anchoring energy as well as its distribution.

Equation 1 was derived for a system with planar anchoring of the nematic on the grating surface. In the VCT cell, the anchoring is homeotropic and so $W\phi$ is zero. A

15   non zero value for $W\phi$ only occurs when a field is applied to the cell as this forces the director into a planar orientation near the grating surface. As the voltage is increased the planar orientation is forced closer to the grating surface and so $W\phi$ increases. The twist threshold will occur when;

20

$$W_\phi(V) > W_t$$

where W_t is the twist threshold energy. It is clear from the above argument that smaller groove depths or larger groove pitches are preferred to keep $W\phi$ small until the nematic is planar throughout the majority of the cell thickness, thus leading to

25   wider viewing characteristics.

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Considering the presented data, the curves in Figure 7 share a common capacitance curve (Figure 6) as this mainly independent of groove depth. Thus the cells with shallower gratings (0.085μm and 0.185μm) consist of a substantially planar structure
5   when the optical transmission begins to rise. They are therefore expected to have better viewing characteristics than the cells made with deeper gratings. The viewing characteristics were measured for two VCT cells, one with shallow grooves and one with deep grooves.

10   Figure 8 shows the contrast ratio as a function of viewing orientation for the cell with deep grating grooves (0.4μm). The two data sets used to calculate the contrast were recorded at 15V and at the threshold voltage. Good viewing characteristics are observed in the vertical direction but the contrast falls off quickly in the horizontal direction. Indeed by about ±20°, the contrast in less than 10:1. A second set of
15   viewing data are shown in Figure 9 for a cell with shallow grating grooves (0.1μm). In this case the viewing characteristics are much better with virtually the entire viewing cone having a contrast of >10:1. Comparison of Figure 9 and Figure 8 confirms that better viewing characteristics are obtained from VCT cells with shallower grooves.

20   The response times of the VCT switching were measured as a function of cell thickness. The results are shown in Figure 10. The switching times were measured for a 0 to 15 V switch. The switch-on time was fitted with an exponent of 1.494 while the switch-off time has an exponent of 2.241. These are respectively less than and greater than the quadratic power law which is measured for both the ON and OFF
25   times in a TN device. The fastest times recorded for the VCT at room temperature were 29ms (t_{on}) and 18ms (t_{off}). These are similar to typical TN devices.

In summary the above results show that the VCT mode offers a steep optical response with a low capacitance change, good viewing characteristics with reasonable switching speeds. The above cells did show reverse twist disclinations but these can easily be removed by adding a small amount of chiral dopant to the nematic or by ensuring that groove direction on the homeotropic surface is not orthogonal to the anchoring direction on the planar surface. The grating profile may be optimised to achieve the steepest optical response with good viewing properties by the use of asymmetric groove profiles or surfaces containing more than one modulation. Tests have shown that a large asymmetry in the groove profile totally inhibits the twist threshold despite the groove depth and pitch being similar to the cells described above.

Typical values for the a and L are 0.3μm and 1.0μm in the range of about 0.05μm to 5μm and 0.10 to 10μm respectively.

Example 2:

A VCT device can also be made in which the homeotropic surface is a rubbed polymer overcoated with a surfactant. One such device was made as follows. The polyimide material AL5417 (JSR) was spin coated onto ITO coated glass, baked for 1 hour at 180°C and rubbed. Next a lecithin solution (0.1% by weight in isopropanol) was placed on the polyimide surface and left for 60 seconds before removal by spinning. This surface was then constructed into a cell in which the opposite surface was a rubbed polyimide (AL5417) without a lecithin treatment. The rubbing directions were orthogonal to each other and the cell thickness was 6μm. The cell was filled with EN38 (Chisso) in its isotropic phase followed by cooling to room temperature.

The cell was positioned with crossed polarisers along the rubbing directions. When a voltage was applied, the transmission remained low until a voltage of 6.5 V was reached. Above 6.5 V, the transmission increased and eventually saturated at about 15 V. This cell was found to have a good viewing angle and only exhibited a small change in capacitance above 6.5 V.

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CLAIMS

1. A liquid crystal device comprising:

5   a layer of nematic or chiral nematic liquid crystal having a negative dielectric
anisotropy;

two containing walls, spaced apart and each so treated as to align the liquid crystal
adjacent to them and carrying electrodes or other means to impose a field on the
10   liquid crystal layer;

means for distinguishing between two different optical states;

15   CHARACTERISED BY:

an aligning surface treatment at one cell wall providing a substantially planar or tilted
alignment of the liquid crystal with a defined azimuthal first alignment direction;

20   an aligning surface treatment on the second cell wall capable of separately providing
both a preferred, substantially homeotropic alignment of the adjacent liquid crystal,
and a defined azimuthal second alignment direction to the adjacent liquid crystal
dependant upon liquid crystal molecular arrangement;

25   the first and second azimuthal alignment directions being at a non zero angle to one
another;

the arrangement being such that the liquid crystal material may adopt a twisted and a
substantially non twisted molecular arrangement dependant upon applied electric
30   fields.

2. The device of claim 1, wherein the two azimuthal alignment directions are within 10° of being perpendicular.

3. The device of claim 1, wherein the aligning surface treatment on the second cell wall includes a grating structure and a homeotropic alignment treatment.

4. The device of claim 1, wherein the aligning surface treatment on the second cell wall includes a rubbed polymer and a homeotropic alignment treatment

5. The device of claim 1, wherein the aligning surface treatment on the second cell wall includes an anisotropic photoactive polymer layer.

6. The device of claim 1, and further including an active matrix of switching elements on one containing wall.

7. The device of claim 1, wherein the means for distinguishing between two different optical states comprises two polarising films aligned such that their axes are substantially crossed and parallel and/or perpendicular to the two azimuthal alignment directions.

8. The device of claim 1, wherein the means for distinguishing between two different optical states includes a dichroic dye and one or more polarisers.

9. The device of claim 3, wherein the shape of the grating surface varies between pixels or within one pixel.

10. The device of claim 3, wherein groove direction on the grating surface is constant or varying between pixels or within one pixel.

11. The device of claim 3, wherein the grating has an asymmetric groove profile.

12. The device of claim 3, where the grating contains more than one modulation.

Fig.1.

Fig.2.

Fig.3.

Fig.4.

Fig.5(a) V=0

A

B

17
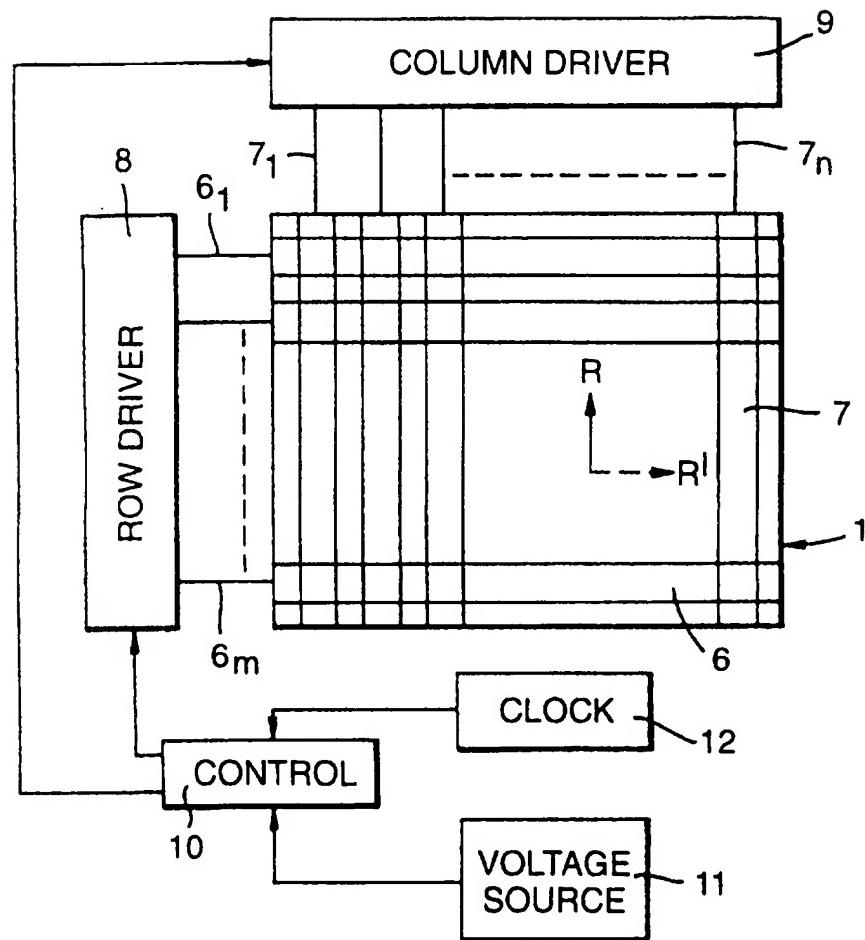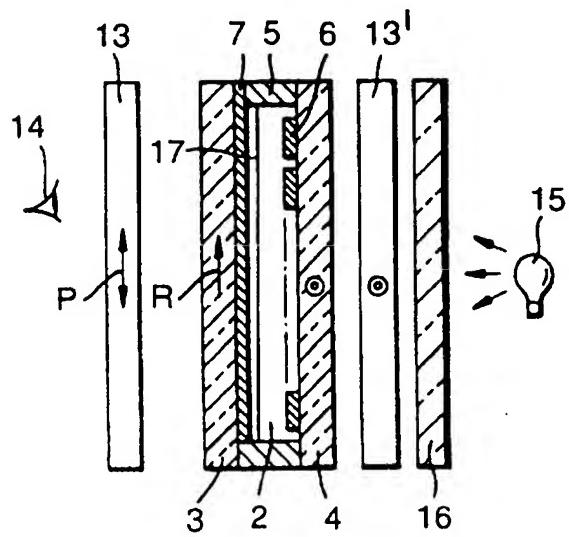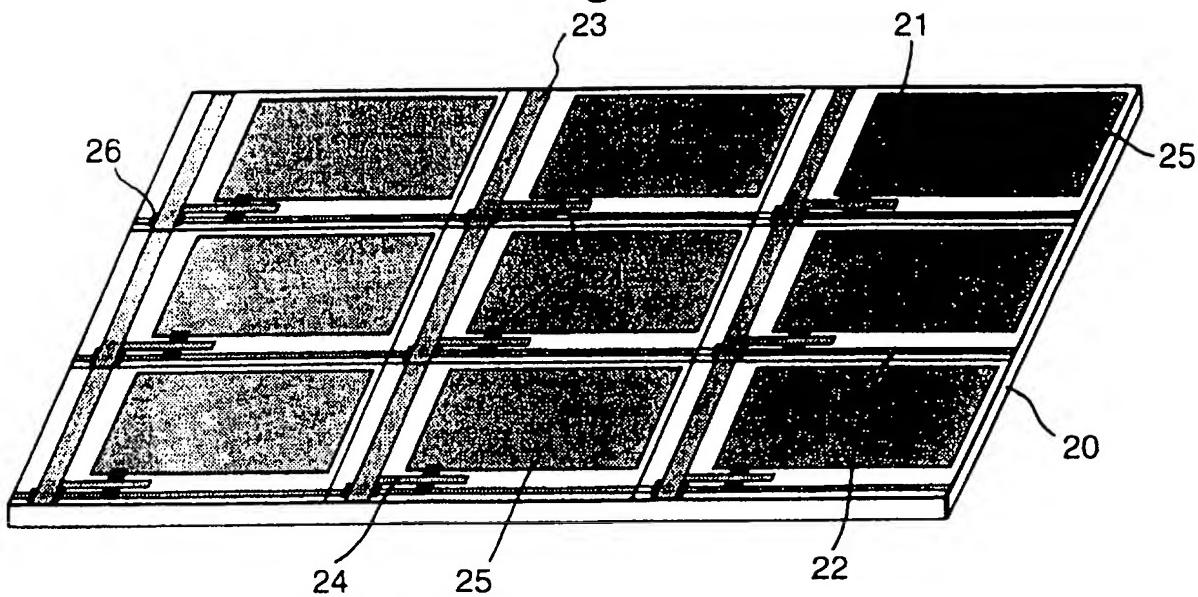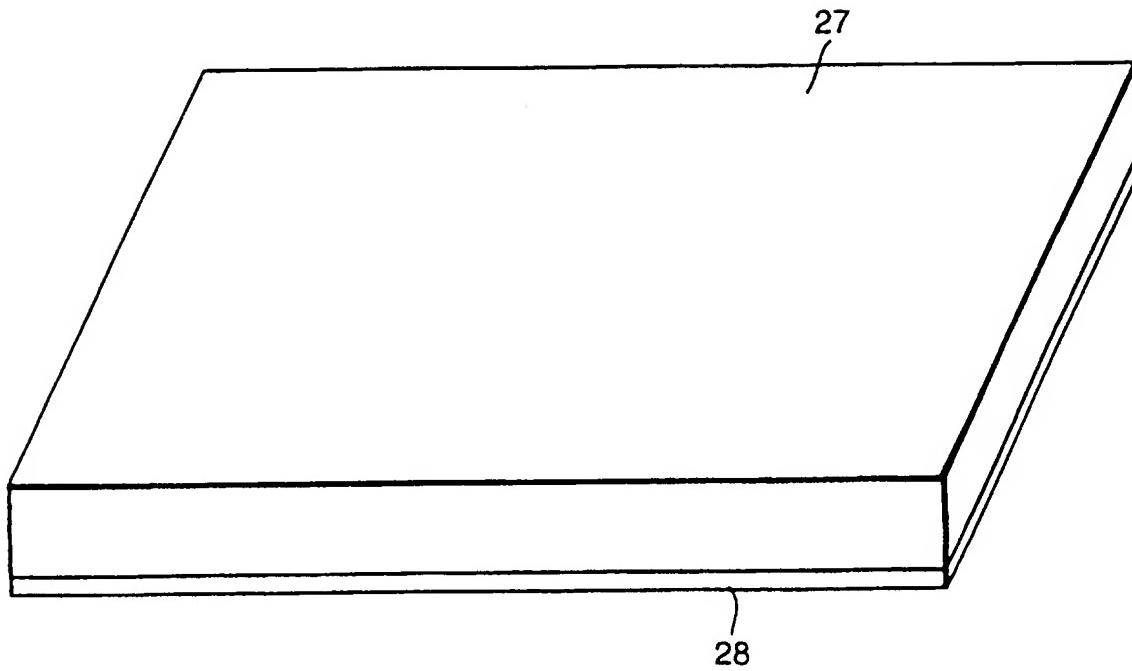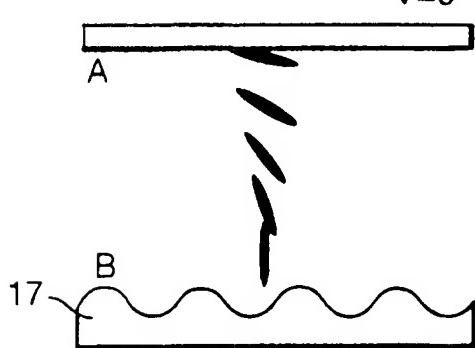
Fig.5(b) V=V₁

Fig.5(a)V=V₂
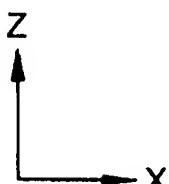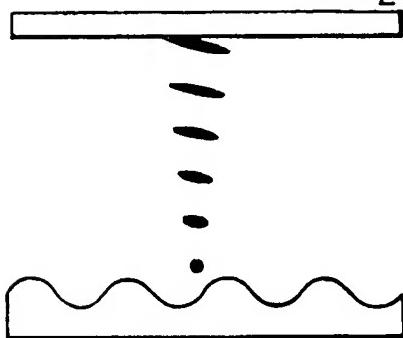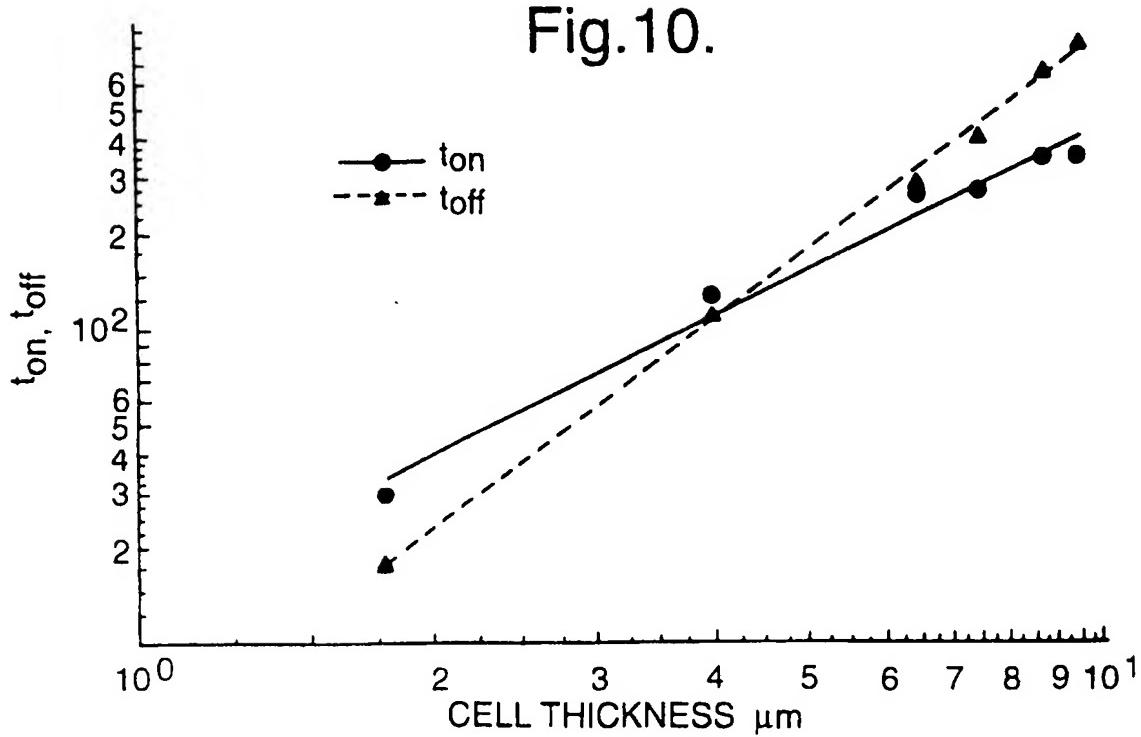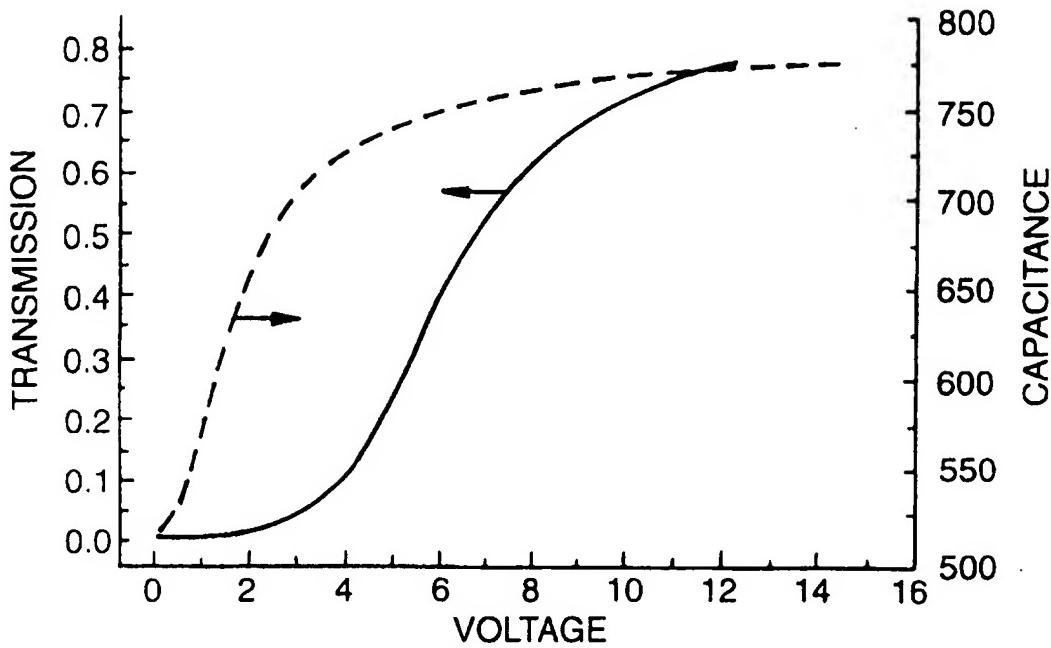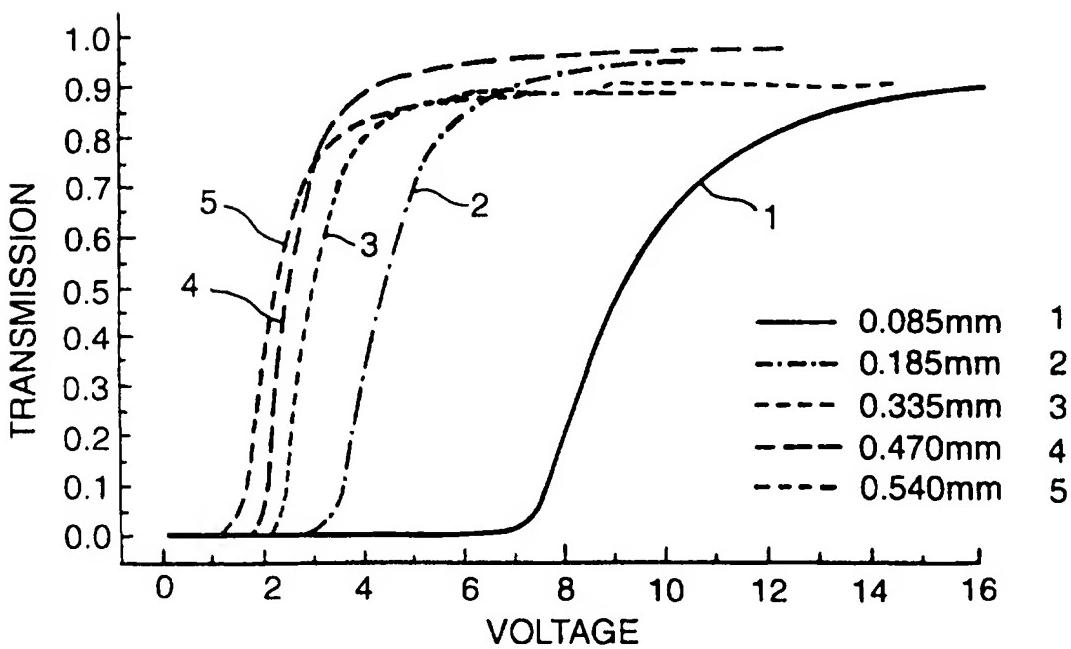
Z

X

Fig.10.

CELL THICKNESS μm

t_{on}, t_{off}

ton

toff

Fig.6.

Fig.7.

|		
——	0.085mm	1
—·—·	0.185mm	2
– – –	0.335mm	3
— —	0.470mm	4
- - -	0.540mm	5

Fig.8.
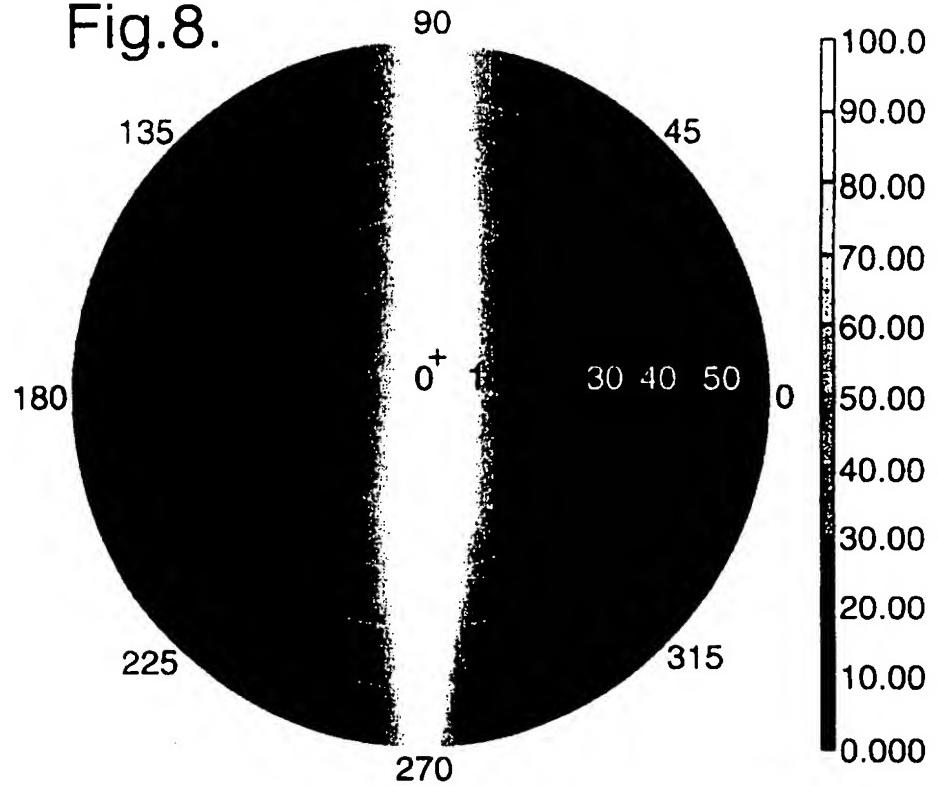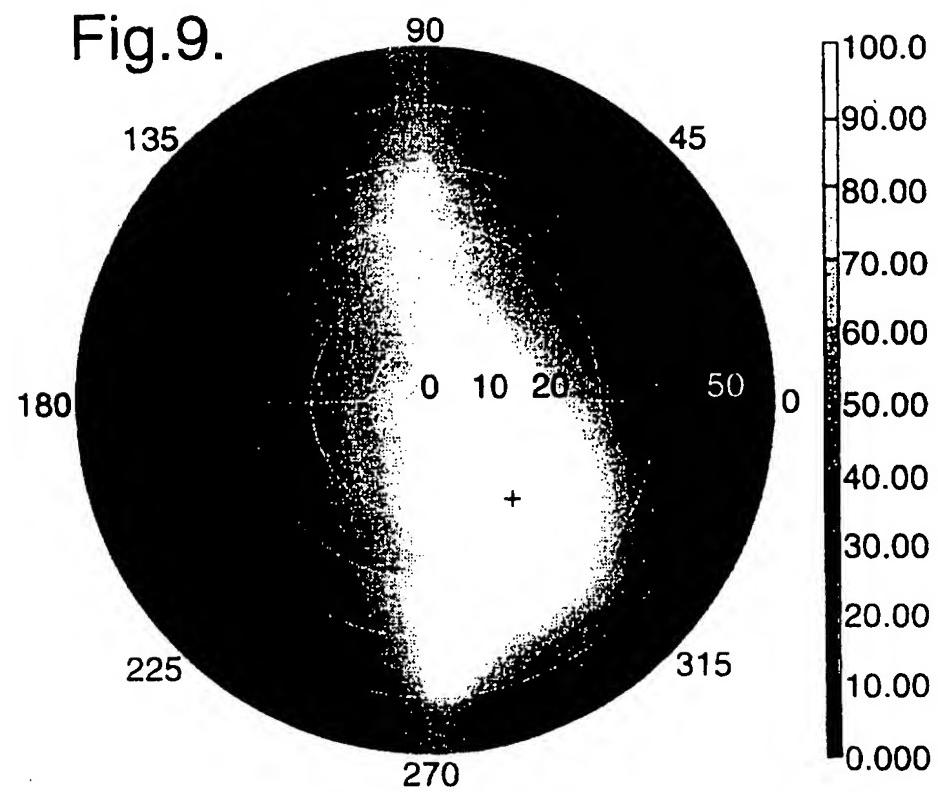
Fig.9.

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G02F1/139   G02F1/1337

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed byclassification symbols)
IPC 6   G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 95 00879 A (UNIV CASE WESTERN RESERVE) 5 January 1995 see page 2, last paragraph - page 4, paragraph 1 ---	1,3,7
A	EP 0 433 999 A (STANLEY ELECTRIC CO LTD) 26 June 1991 see page 4, line 26 - page 5, line 53 -----	1,4

☐ Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 June 1997	11/07/1997

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European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Wongel, H

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9500879 A	05-01-95	US 5477358 A CN 1125986 A EP 0737326 A JP 8511881 T US 5602662 A	19-12-95 03-07-96 16-10-96 10-12-96 11-02-97
EP 0433999 A	26-06-91	JP 3192220 A JP 8012360 B DE 69026047 D DE 69026047 T US 5182664 A	22-08-91 07-02-96 25-04-96 31-10-96 26-01-93